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SUMMIT
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SOFIA UNIVERSITY - MARKING MOMENTUM FOR INNOVATION AND TECHNOLOGICAL TRANSFER

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Accessibility of Braille Texts for the Visually Impaired Produced with Different 3D Printing Technologies

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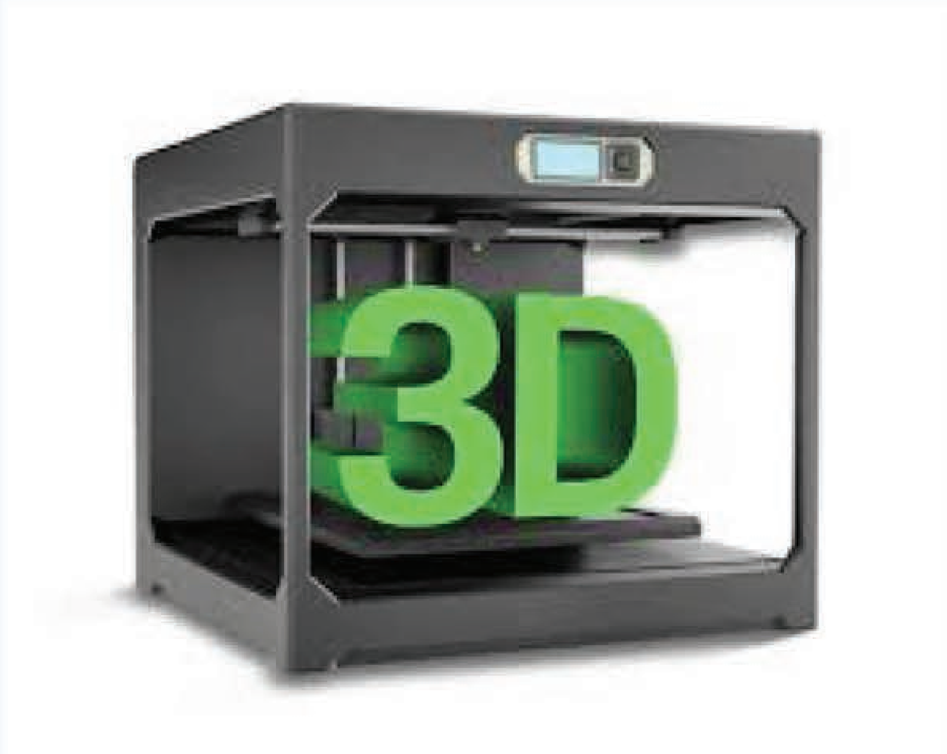


INTRODUCTION

The advancement of modern industry has resulted in a growing need for high-performing materials, with tensile mechanical properties serving as a crucial indicator of material excellence (*Hanjun Wei et al., 2024*), (*Paneva M., et al., 2023*). Conventional methods of material design rely on empirical knowledge, and trial and error. However, with the continuous progress of computer technology and artificial intelligence, machine learning has opened up new possibilities for material design. 3D printing became in time very popular and accessible due to the cost-effective prototyping and production of parts for various applications, including Braille materials for Visually Impaired individuals. The rapid increase in the use of 3D technologies, especially 3D printing, contributes to lowering the costs of purchasing and maintaining this type of equipment including in an aggressive environment (*Paneva M. et al., 2023*). 3D printing is a suitable method for creating details and objects of cultural and historical heritage that can be presented to blind or visually impaired people. Scanning objects using 3D scanners is not yet so accessible in terms of accuracy, but it is suitable for creating irresponsible details. Objects created from 3D models independently through 3D modeling, 3D scanning, or photogrammetry can be felt and give information about the shape, details, and dimensions of a given object to disadvantaged people.

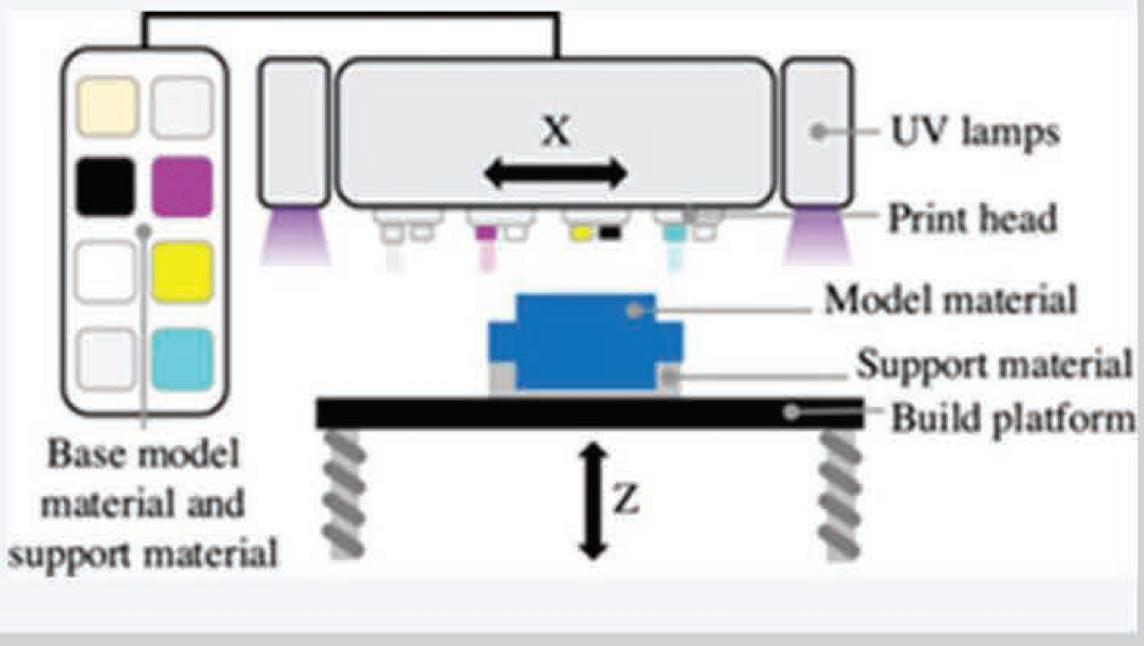
STATE OF THE ART

Braille texts have been considered for centuries as classical for access of Visually Impaired individuals to written information since Braille was developed in 1825 and became in time internationally accepted and recognized. Although the traditional Braille writing tools include the Braille slate (frame), stylus, and Braille machine, 3D-produced Braille texts are making high progress in recent years (Tzvetkova-Arsova, et al, 2022).

Part of the team has experience in 3D Braille content creation for visually impaired or blind people. An exhibition of tactile goblins for the blind was organized, and visited by over 11 000 people (*Cantoni, V. et al. 2016*). A tactile painting of a masterpiece was also created in an art gallery in Milan [*Picanoteca di Brera*]. An exhibition was held in Bulgaria to celebrate the city of Sofia as the capital, among many paintings 10 were selected, which were made into 3D tactile paintings. In addition, paintings of historical scenes of Bulgaria were made (*Gyoshev S. et al.(2018) a, b*)

For the purposes of this research, 3D printers from three different printing technologies were employed. These 3D printers include **FDM, PolyJet, and ColorJet technologies.**

Figure 1. Illustration of PolyJet 3D printing. (SUP706B. Stratasys. (n.d.), 2022)



METHODOLOGY

For this research, a variety of tactile Braille plates were produced using the above-listed technologies. Ten Visually Impaired adults, who are Braille users (4 women and 6 men) aged 20-40, participated in the research. They were given the produced Braille plates and were asked about the following tactile characteristics:

- best or preferred material;
- most readable plate;
- most pleasant to the touch plate;
- durability of the plate.

The Visually Impaired participants in the investigation reported that the tactile Braille tiles from FDM and ColorJet technologies are not as friendly to the touch as PolyJet 3D printing technology, despite the different variants. For this reason, research has been in-depth on polyjet and its 3D printing properties and variants. For the study, 3 variants of 3D printing were carried out, depending on the printing characteristics and the surface layer (rounded and without rounding). The plates with rounded Braille dots were more pleasant for reading, as the hand could easily follow the line. The reading was closest to reading Braille written on standard paper. The used VeroWhite material 1 (fig. 3 b) white transparent plates)) was reported to be very pleasant to the touch and seemed durable.

RESULTS

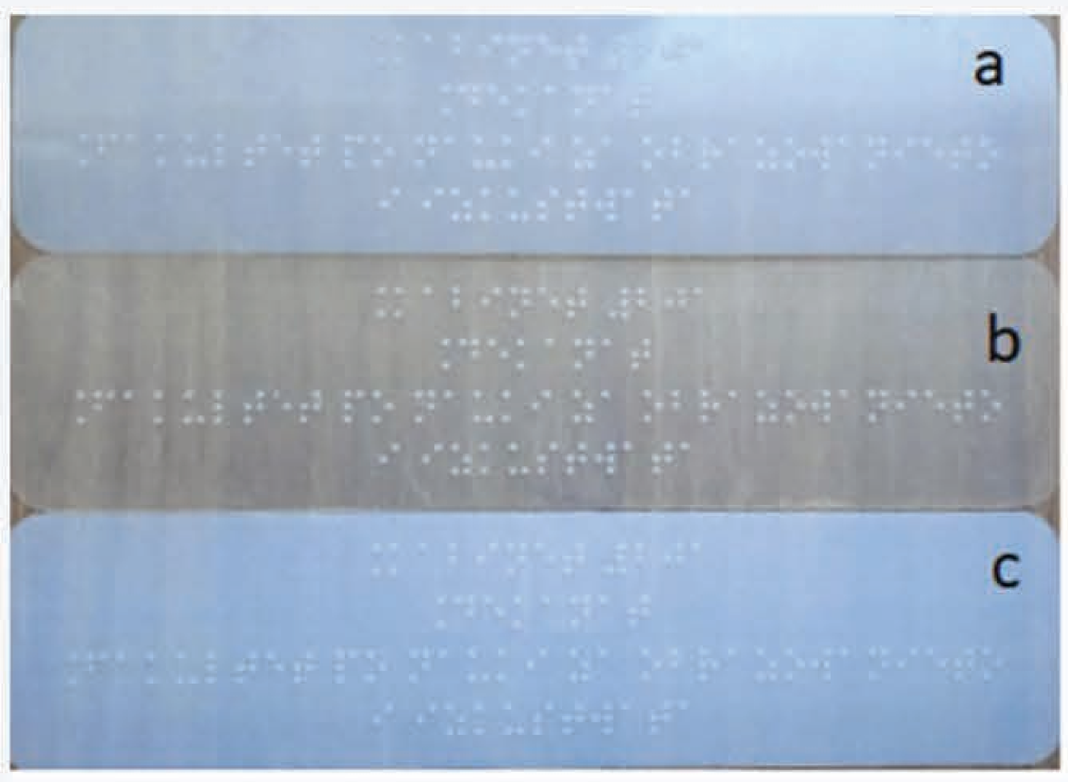


Figure 2. Braille plates - VeroWhite Material 1 - rounded without glossy finish

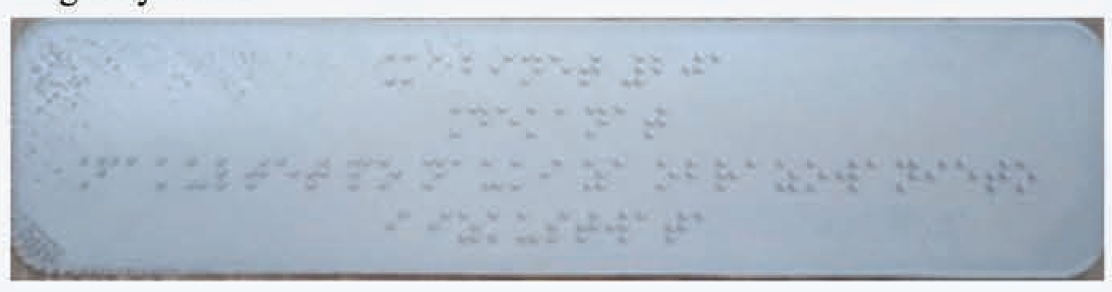


Figure 3. Braille plates - PLA Material 2 - with and without rounding.

Figure 4. Braille plates - Tango Material 3 with and without rounding/ with and without glossing

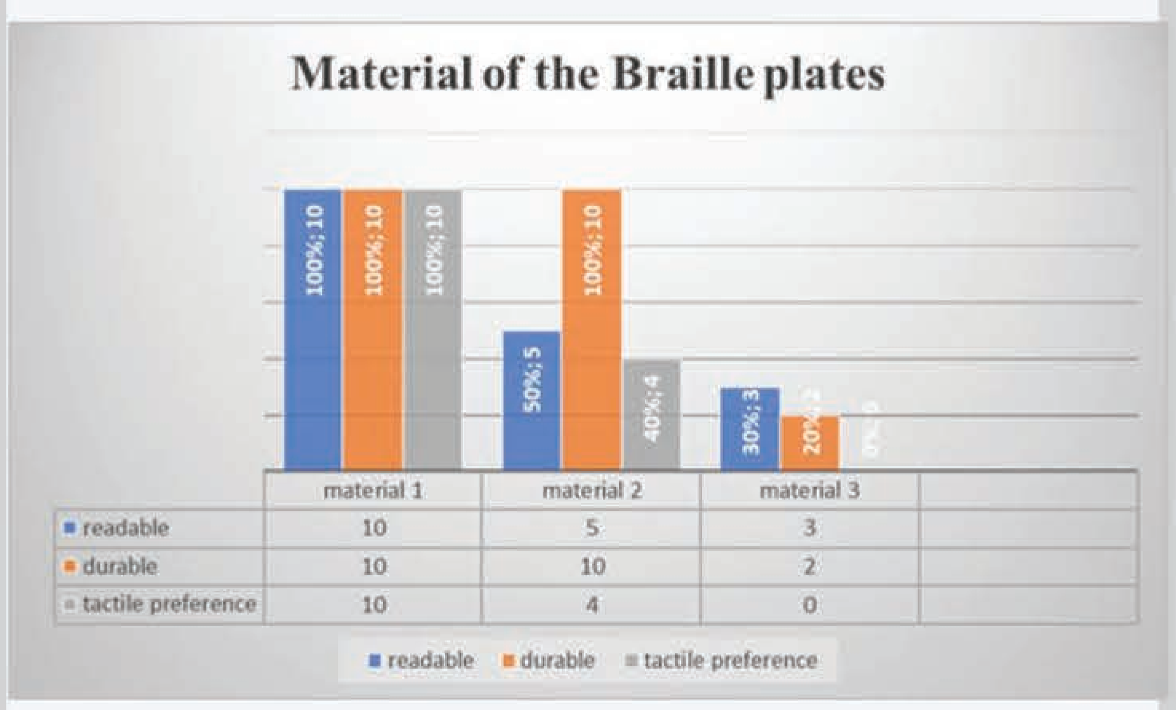
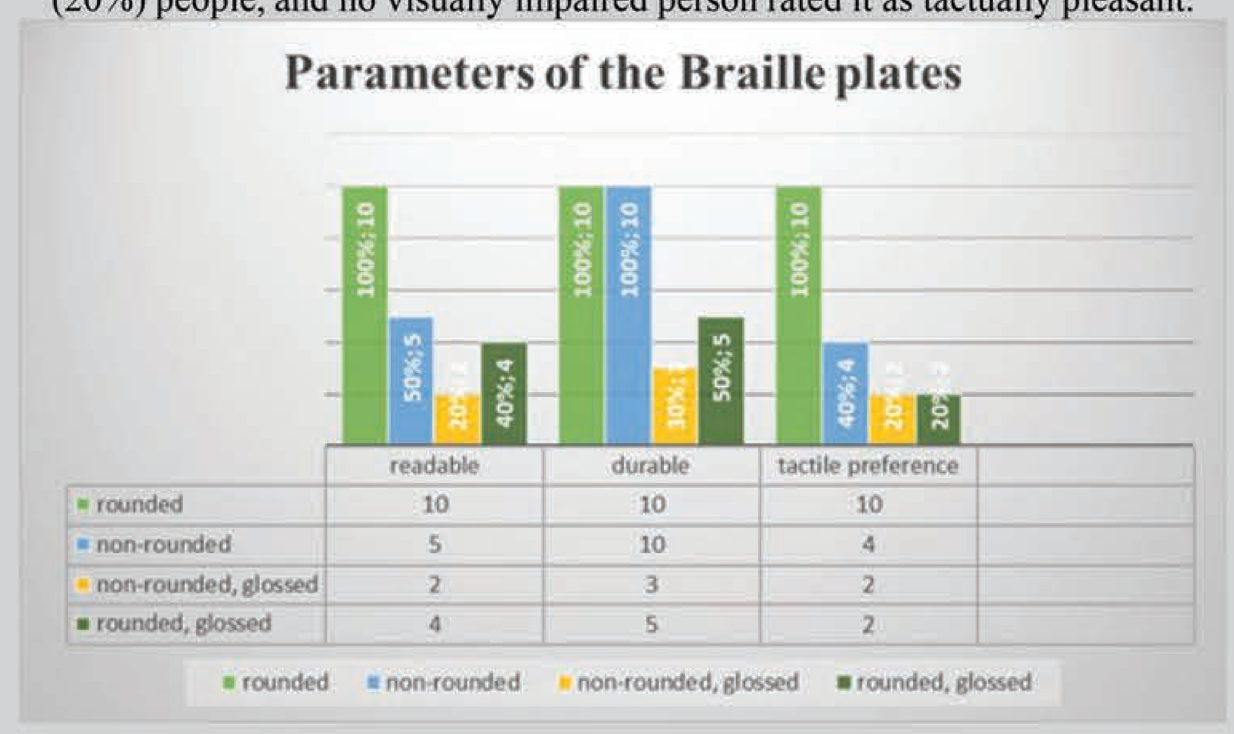


Diagram 1 shows the responses of the visually impaired participants according to the preferred material. 100% (10) of them rated material 1 as the most readable, tactually fine, and the most durable. For material 2, only 5 (50%) people gave feedback that it was readable, 10 (100%) thought it was durable, and only 4 (40%) described it as pleasant to the tactile sense. Material 3 was rated as the least readable by 3 (30%) people, not durable by 2 (20%) people, and no visually impaired person rated it as tactually pleasant.



In Diagram 2, the numerical reflection of responses among visually impaired individuals for different parameters of braille plates is presented. It is evident that plates with rounded edges of the braille dots are unanimously regarded as readable, durable, and pleasant to tactile touch by all participants (10/100%). Regarding tablets with non-rounded edges of the dots, 5 (50%) visually impaired individuals share that they are readable, 10 (100%) consider them durable, and 4 (40%) find them pleasant to touch. The opinions of participants on glossy tablets with non-rounded edges are as follows - 2 (20%) of them perceive them as readable, 3 (30%) assess them as durable, and 2 (20%) as tolerable for tactile sensation. Tablets with rounded edges of the dots and glossy, according to 4 (40%) visually impaired individuals, are readable, 5 (50%) describe them as durable, and again only 2 (20%) find them tolerable for tactile sensation.

The presented plates were made with a Braille cell size font 1 and font 2. There are no significant differences in readability between the two fonts; however, for most, the second font 2 is preferred as it is clearer and more pleasant. Only one individual describes font 1 as more compact.

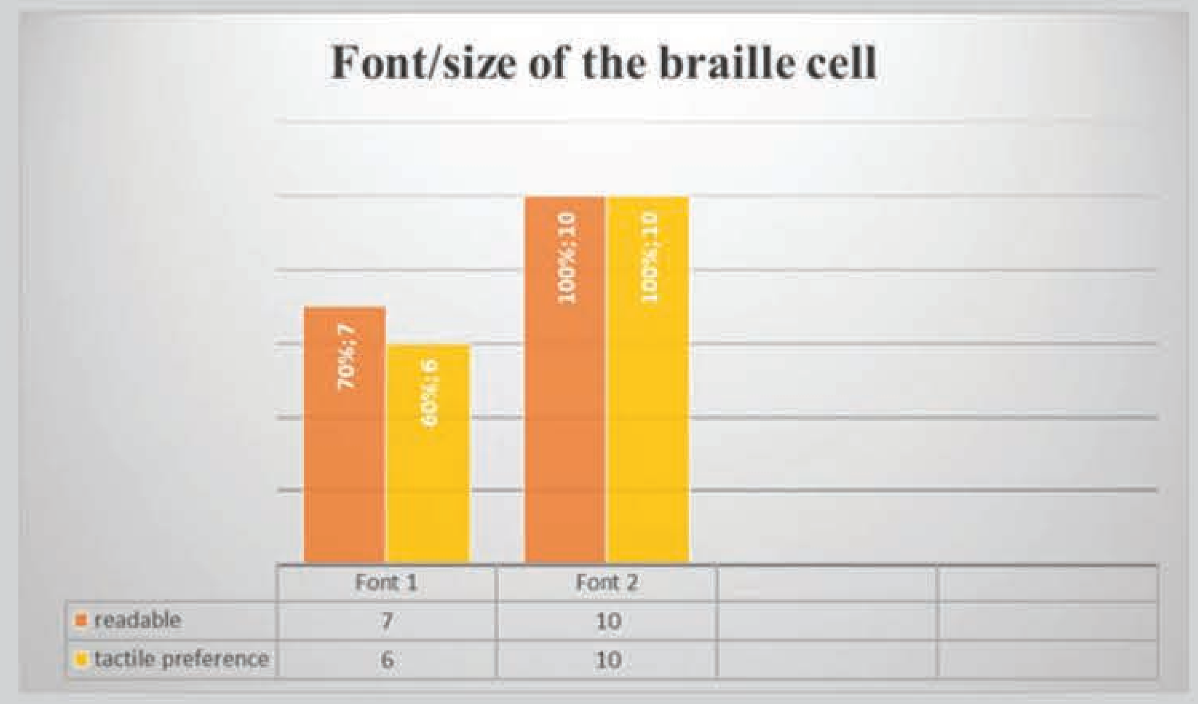


Diagram 3 presents the participants' opinions on the braille cell size, assessed in terms of readability and tactile feel. From the results, it becomes clear that the braille cell size with font 2 is considered most suitable by all participants (10/100%). For font 1, 7 (70%) individuals determine it to be readable, while 6 (60%) state that it is understandable in terms of tactile feel. In both sizes of the braille cell, it is accessible and recognizable by the visually impaired participants, but undoubtedly, the one with font 2 is more pleasant and easier for tactile recognition.

CONCLUSIONS

1. Plates with non-rounded dots were also legible, but did not come close in tactile sensation to Braille.
2. Glossy plates were defined as tacky and distracting to the reader. The fingers touched and stopped during reading and got stuck in the intervals which caused a disturbance in the fluency of reading.
3. The size of the braille cell with font 2 was clear and legible and its size was similar to that written by a braille typewriter or printer.
4. The spaces should be adjusted, the size of 1 space was equal to the size of 1 braille cell.
5. The braille plate did not need to have a border/edge at the end.
6. Rounded braille dots were more pleasing to the touch, as well as more recognizable in terms of legibility and durability. While reading and following the line, the hand moved smoothly and the material created a feeling of resistance.

In conclusion, it can be said that 3D printing of Braille materials is both possible and accessible. The best Braille readability by Visually Impaired readers was found for samples achieved by the PolyJet technology.

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